

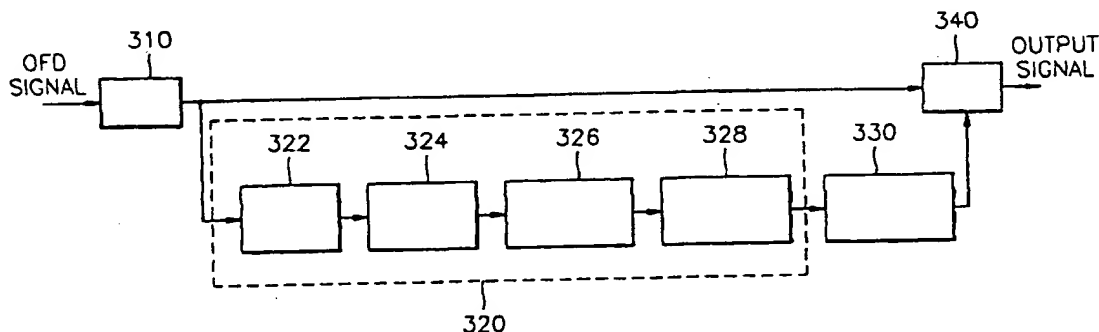
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(54) Title: FFT WINDOW POSITION RECOVERY APPARATUS AND METHOD FOR OFDM SYSTEM RECEIVER



(57) Abstract

A fast Fourier transform (FFT) window position recovery apparatus in an orthogonal frequency division multiplexing (OFDM) receiver is provided. This apparatus, in an OFDM system receiver which receives an OFDM symbol comprised of a useful data interval and a guard interval and recovers an FFT window position, includes: an analog-to-digital converter (ADC) (310) for converting a received OFDM signal into a digital complex sample; a symbol start detector (320) for detecting a power difference between the digital complex samples output by the ADC and detecting a position having a minimum absolute value of the power difference between the samples, as a symbol starting position; and an FFT window controller (330) for activating FFT by moving the FFT window position using symbol start information detected by the symbol start detector (320). The influence of frequency and phase offsets is reduced by using the power difference between adjacent samples delayed by the useful data interval, thus improving the reliability of a system.

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FFT WINDOW POSITION RECOVERY APPARATUS AND METHOD FOR OFDM SYSTEM RECEIVER

Technical Field

5 The present invention relates to an orthogonal frequency division multiplexing (OFDM) system, and particularly, to a fast Fourier transform (FFT) window position recovery apparatus and method in an OFDM receiver.

Background Art

FIG. 1 is a block diagram showing the configuration of a general
10 OFDM system receiver. First, a symbol of an OFDM signal, when N subcarriers are used in the OFDM system, comprises N useful data samples output by transmission inverse fast Fourier transform (IFFT) and a guard interval having the lengths of G samples inserted before a useful data interval to prevent interference between the symbols. Here, the guard
15 interval copies the end portion of the useful data interval. A transmitter (not shown) adds G complex values to N complex values output by an inverse fast Fourier transformer (IFFT), and sequentially transmits a symbol comprised of a total of (G+N) samples. Here, the guard interval is generally longer than a delay spread time of a channel. For example, a European
20 digital TV broadcast standard defines guard intervals having lengths of 1/4, 1/8, 1/16 and 1/32 of an actual symbol length, and a transmission side selects and uses one among the above-described guard intervals. Time synchronization must be accurately performed to allow a receiver to recover a received OFDM signal. Time synchronization is comprised of FFT window
25 position recovery for accurate parallel processing of a signal, and sampling clock recovery for sampling a signal having a maximum signal-to-noise ratio (SNR). A j-th symbol comprised of a useful interval and a guard interval which are output by an IFFT (not shown) of a transmitter is expressed by the following Equation 1:

$$s_j = \sum_{n=-G}^{N-1} x_{j,n} = \sum_{n=-G}^{-1} \sum_{k=0}^{N-1} x_{j,k} e^{j2\pi(N-n)/N} + \sum_{n=0}^{N-1} \sum_{k=0}^{N-1} x_{j,k} e^{j2\pi kn/N} \quad \dots(1)$$

wherein j denotes a symbol number, k is a carrier index, N is the number of effective data samples, and n indicates a sampling time. In the right side of Equation 1, the first term is a guard interval portion, and the second term is a useful data portion.

5 As shown in FIG. 1, an analog-to-digital converter (ADC) 110 samples a received OFDM signal. A symbol start detector 120 receives the sampled OFDM signal and detects a start portion of a symbol. A FFT window controller 130 designates a FFT window point in time to activate a useful data portion of a FFT 140 using the symbol start information detected by the
10 symbol start detector 120. As shown in FIG. 2, the FFT window transmits only the useful data interval excluding the guard interval in a received signal to the FFT. Generally, the symbol start detector 120 of FIG. 1 detects a symbol start portion using either a correlation value between received signals or the quantized values of the input signals. However, the first way
15 requires a maximum position of the correlation value between the received signals, resulting in complicate system realization. The second way provides a simple structure because of the 2-bit quantization. However, when a frequency offset defined as a carrier frequency synchronization error, i.e., a phase difference of $e^{j(\omega_c t + \phi)}$, exists, phase rotation of the input signal occurs
20 to thus change the phases of a guard interval and the end portion of a useful data interval. Thus, a position having a maximum correlation value cannot be found, and symbol starting position recovery is thus difficult.

Disclosure of the Invention

25 It is an object of the present invention to provide a method for recovering a phase error of a FFT window using a power difference between received signals in a predetermined section in an orthogonal frequency division multiplexer (OFDM) receiver.

It is another object of the present invention to provide an apparatus
30 for recovering a phase error of a FFT window using a power difference between received signals in a predetermined section in an OFDM receiver.

To accomplish the first object, there is provided a fast Fourier

transform (FFT) window position recovery method in an orthogonal frequency division multiplexing (OFDM) system receiver which receives an OFDM symbol comprised of a useful data interval and a guard interval and recovers a FFT window position, the method comprising the steps of: (a) 5 converting a received OFDM signal into a digital complex sample; (b) obtaining a power difference between the digital complex sample output by the step (a) and a complex sample value delayed by predetermined samples, and detecting a position having a maximum power value between the samples, as a symbol starting position; and (c) activating FFT while 10 moving the FFT window position using symbol start information detected by the step (b).

To accomplish the second object, there is provided a fast Fourier transform (FFT) window position recovery apparatus in an orthogonal frequency division multiplexing (OFDM) system receiver which receives an 15 OFDM symbol comprised of a useful data interval and a guard interval and recovers a FFT window position, the apparatus comprising: an analog-to-digital converter (ADC) for converting a received OFDM signal into a digital complex sample; a symbol start detector for detecting a power difference between the digital complex samples output by the ADC and detecting a 20 position having a minimum absolute value of the power difference between the samples, as a symbol starting position; and a FFT window controller for activating FFT by moving the FFT window position using symbol start information detected by the symbol start detector.

25 Brief Description of the Drawings

FIG. 1 is a block diagram showing the configuration of a general orthogonal frequency division multiplexing (OFDM) system receiver;

FIG. 2 is a concept view for explaining a fast Fourier transform (FFT) window in the FFT window controller of FIG. 1;

30 FIG. 3 is a block diagram of a FFT window position recovery apparatus in an OFDM system receiver according to the present invention;

FIG. 4 is a block diagram of the power difference detector 324 of FIG.

3; and

FIG. 5 is a concept view for FFT window position search.

Best mode for carrying out the Invention

5 Referring to FIG. 3, a FFT window position recovery apparatus in an OFDM receiver according to the present invention receives an OFDM signal, and is comprised of an analog-to-digital converter (ADC) 310, a starting position detector 320, a FFT window position controller 330, and a fast Fourier transformer (FFT) 340. Here, the starting position detector 320
10 includes a power detector 322, a power difference detector 324, a slide window adder 326, and a maximum value position detector 328.

Referring to FIG. 4, the power difference detector 324 of FIG. 3 is comprised of an N sample delay 410 and a power difference calculator 328.

15 FIG. 5 is a concept view for FFT window position recovery according to the present invention.

The operation and effects of the present invention will now be described referring to FIGS. 1 through 5.

First, an OFDM signal output by a transmission port (not shown) has not only noise but also a phase error or frequency error, and is a complex
20 signal as expressed in Equation 2:

$$y(t) = s(t) \cdot e^{j(\omega_0 t + \phi)} + n(t) \quad \dots(2)$$

wherein $s(t)$ is a transmission signal, ω_0 is a frequency error, ϕ is a phase error, and $n(t)$ is a noise.

The ADC 310 samples the input OFDM signal as expressed in
25 Equation 2, and converts the OFDM signal into digital data as expressed in Equation 3:

$$y(k) = y(t), t = kT \quad \dots(3)$$

wherein $y(k)$ is a complex sample, $y(t)$ is a received OFDM signal, k is 0, 1, 2, ..., and T is a rated sampling period.

30 The symbol start detector 320 obtains a power difference between an input complex sample $y(k)$ and an input complex sample delayed by N samples, and detects a position having a minimum power value between the

samples, as a symbol starting portion. That is, in order to remove the influence of a phase/frequency error (phase/frequency error between $r_i(n)$ and $r_i(n+N)$ shown in FIG. 5), the power detector 322, as shown in FIG. 3, detects a power value $P(k)$ of the complex signal $\gamma(k)$ as expressed in
 5 following Equation 4:

$$P(k) = \gamma(k)_I^2 + \gamma(k)_Q^2 \quad \dots(4)$$

wherein $\gamma(k)_I$ is an in-phase component of $\gamma(k)$, and $\gamma(k)_Q$ is a quadrature component of $\gamma(k)$.

The power difference detector 324 obtains a power difference
 10 between two samples spaced by N samples from each other.

That is, as shown in FIG. 4, the power difference calculator 420 calculates a difference between a power value $P(k)$ output by the power detector 322 and a power value delayed by N samples by the N sample delay 410. Referring to the concept view of FIG. 5, a first block BLOCK1 is
 15 a sample value stored from an arbitrary position (0) to a symbol length $(N+G)$, and a second block BLOCK2 is a sample value stored from the start point in time N to a symbol length $(2N+G)$. If a guard interval (G) in the first block BLOCK1 is N samples delayed from the storing position by the N sample delay 410, then it is on the same level as the end portion of useful
 20 data interval (G') in the second block BLOCK2 having the same data as the guard interval (G). In the correlation between the first and second blocks BLOCK1 and BLOCK2, the sections G and G' are most closely correlated with each other because they have the same data. The residual sections hardly have correlation with each other because they have arbitrary data.
 25 Accordingly, the difference between a power value delayed by N samples and a power value of a received signal is "0" in a portion of the useful data interval having the same data as the guard interval (in the state of no noise). However, in the remaining portion, a positive or negative difference value (direction) between arbitrary sample values is generated. Here, when the
 30 positive or negative value is used without change, it is difficult to discriminate the guard interval from the other interval. Thus, the absolute value of the difference is obtained to take only the value of the received signal regardless

of the sign thereof. The slide window adder 326 adds the power difference values output by the power difference detector 324 within the guard interval (G). The slide window adder 326 performs addition while moving a window from the start point in time 0 to a point of time N+G in units of one sample.

5 As shown in FIG. 5, the output value of the slide window adder 326 is minimum at a symbol start point in time (i). The minimum value position detector 328 detects a sample position having a minimum value among the output values of the slide window adder 326, and detects the point of time with respect to the minimum value as the symbol starting point.

10 The operations of the power detector 322, the power difference detector 324, the slide window adder 326, and the minimum value position detector 328 can be expressed in the following Equation 5:

$$Mim_{\theta} = \sum_{n=0}^{\theta+G-1} |p_i(n) - p_i(n+N)|, \quad p_i(n) = |Y_i(n)|^2 \text{ or } |Y_i(n)| \quad \dots(5)$$

Thus, minimum value position information detected by the minimum value position detector 328 becomes an FFT window moving value of the
15 FFT window position controller 330. The FFT window position controller 330 designates the position where fast Fourier transform (FFT) is activated by the FFT 340 using position information of the minimum value detected by the minimum value position detector 328. The FFT 340 fast-Fourier-transforms data generated by the ADC 310 according to a FFT window position control
20 signal generated by the FFT window position controller 330.

Industrial Applicability

According to the present invention as described above, the influence of frequency and phase offsets is reduced by recovering a FFT window
25 phase error using the power difference between received signals in a predetermined interval in an OFDM receiver, thus improving the reliability of a system.

What is claimed is:

1. A fast Fourier transform (FFT) window position recovery method in an orthogonal frequency division multiplexing (OFDM) system receiver which receives an OFDM symbol comprised of a useful data interval and a guard interval and recovers a FFT window position, the method
5 comprising the steps of:

- (a) converting a received OFDM signal into a digital complex sample;
- (b) obtaining a power difference between the digital complex sample output by the step (a) and a complex sample value delayed by
10 predetermined samples, and detecting a position having a maximum power value between the samples, as a symbol starting position; and
- (c) activating FFT while moving the FFT window position using symbol start information detected by the step (b).

15 2. A fast Fourier transform (FFT) window position recovery apparatus in an orthogonal frequency division multiplexing (OFDM) system receiver which receives an OFDM symbol comprised of a useful data interval and a guard interval and recovers a FFT window position, the apparatus comprising:

- 20 an analog-to-digital converter (ADC) for converting a received OFDM signal into a digital complex sample;
- a symbol start detector for detecting a power difference between the digital complex samples output by the ADC and detecting a position having a minimum absolute value of the power difference between the samples, as
25 a symbol starting position; and
- a FFT window controller for activating FFT by moving the FFT window position using symbol start information detected by the symbol start detector.

3. The FFT window position recovery apparatus in an OFDM
30 system receiver as claimed in claim 2, wherein the symbol start detector comprises:

- a power detector for detecting a power value of the digital complex

samples output by the ADC;

a power difference detector for detecting a difference between a power value output by the power detector and a power value delayed at the interval of predetermined samples;

5 a slide window adder for adding the power difference output by the power difference detector while moving the power difference values by every sample within the guard interval; and

a minimum value position detector for detecting a minimum among the output values of the slide window adder.

10

4. The FFT window position recovery apparatus in an OFDM system receiver as claimed in claim 3, wherein the power difference detector comprises:

15 a delay for delaying by predetermined samples the power values of the digital complex samples output by power detector;

a power difference calculator for calculating a difference between a power value of the digital complex samples output by the power detector and a power value delayed by the delay.

20 5. The FFT window position recovery apparatus in an OFDM system receiver as claimed in claim 4, wherein the delay is delayed by a useful data interval.

25 6. The FFT window position recovery apparatus in an OFDM system receiver as claimed in claim 3, wherein the minimum of the minimum position detector is a power value of a portion of the useful data interval which has the same data as the guard interval.

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FIG. 1

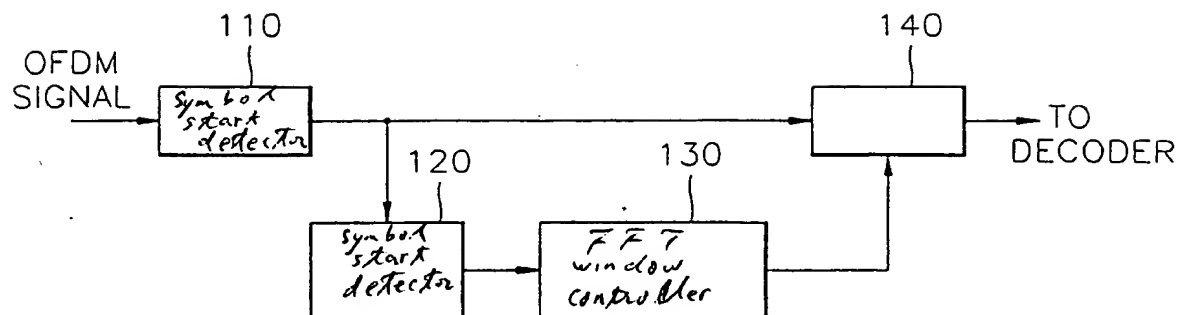
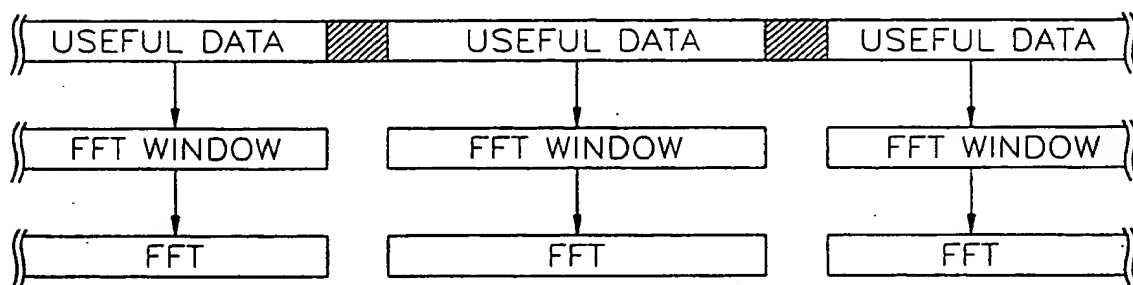
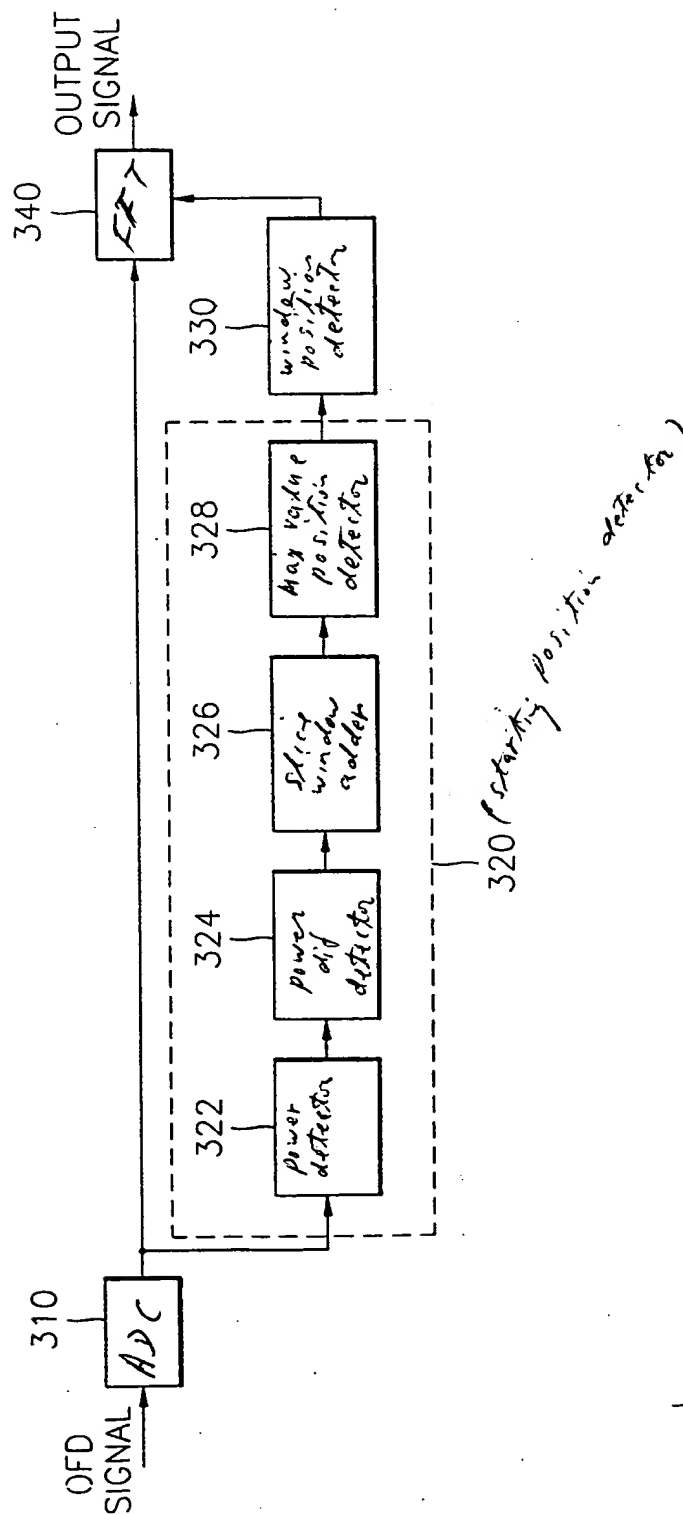


FIG. 2



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FIG. 3



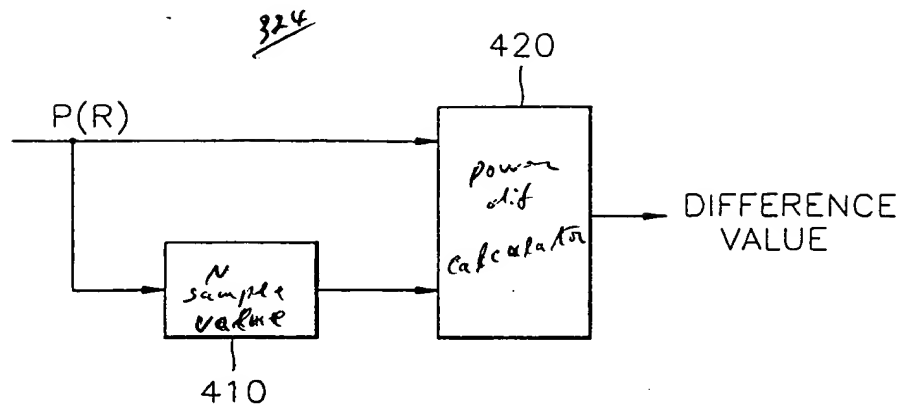
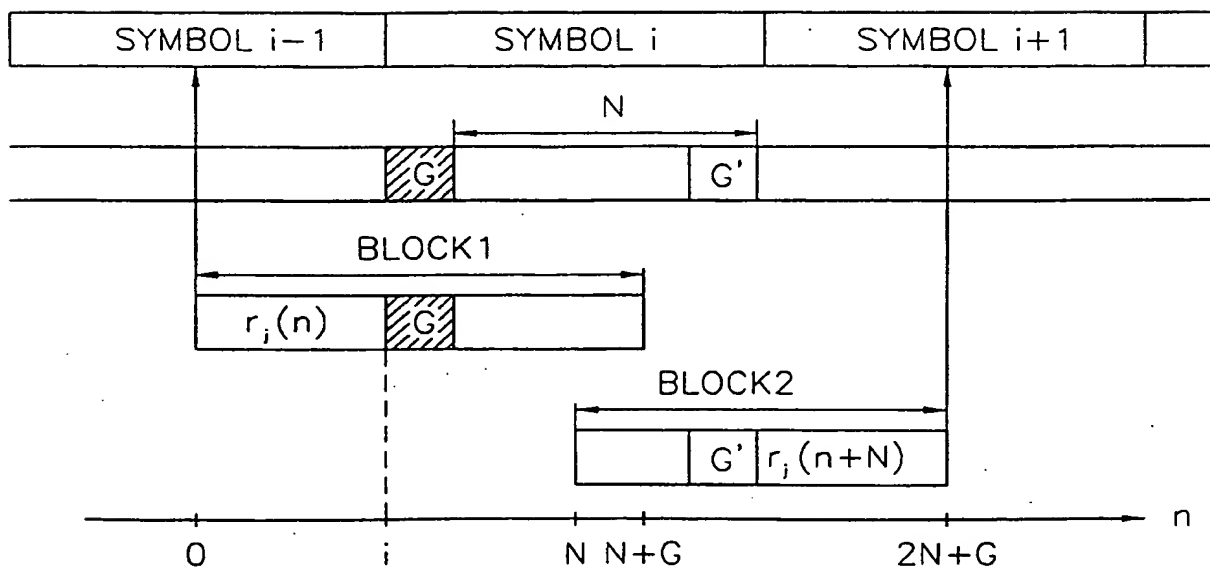
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FIG. 4

FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR 98/00300

A. CLASSIFICATION OF SUBJECT MATTER

IPC⁶: H 04 L 5/06; H 04 N 7/06

According to International Patent Classification (IPC) or to both national classification and IPC

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|--|-----------------------|
| A | EP 0 730 357 A2 (TELIA AB) 04 September 1996 (04.09.96), abstract; fig.1. | 1,2 |
| A | WO 97/07 620 A1 (PHILIPS ELECTRONICS) 27 February 1997 (27.02.97), abstract. | 1,2 |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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05 March 1999 (05.03.99)

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| EP A2 730357 | 04-09-96 | EP A3 730357 NO A0 960759 NO A 960759 SE A0 9500743 SE A 9500743 US A 5812523 | 08-04-98 26-02-96 02-09-96 01-03-96 02-09-96 22-09-98 |
| WD A1 9707620 | 27-02-97 | CA AA 2202752 EP A1 786183 JP T2 10507616 US A 5848107 | 27-02-97 30-07-97 21-07-98 08-12-98 |